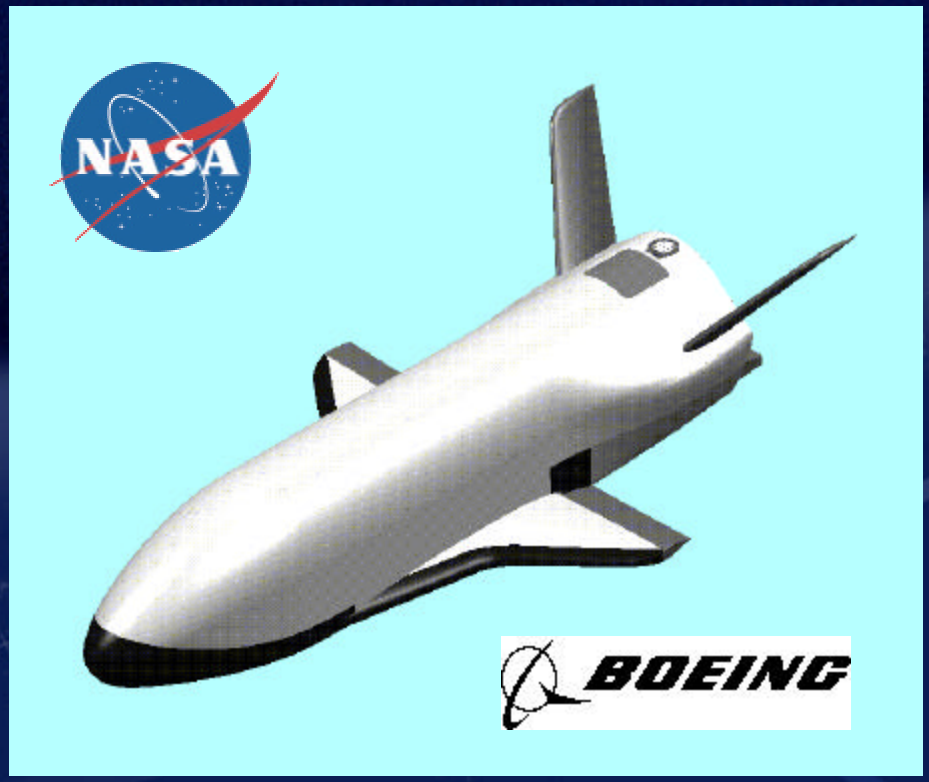

The NASA IVHM Technology Experiment for X-37

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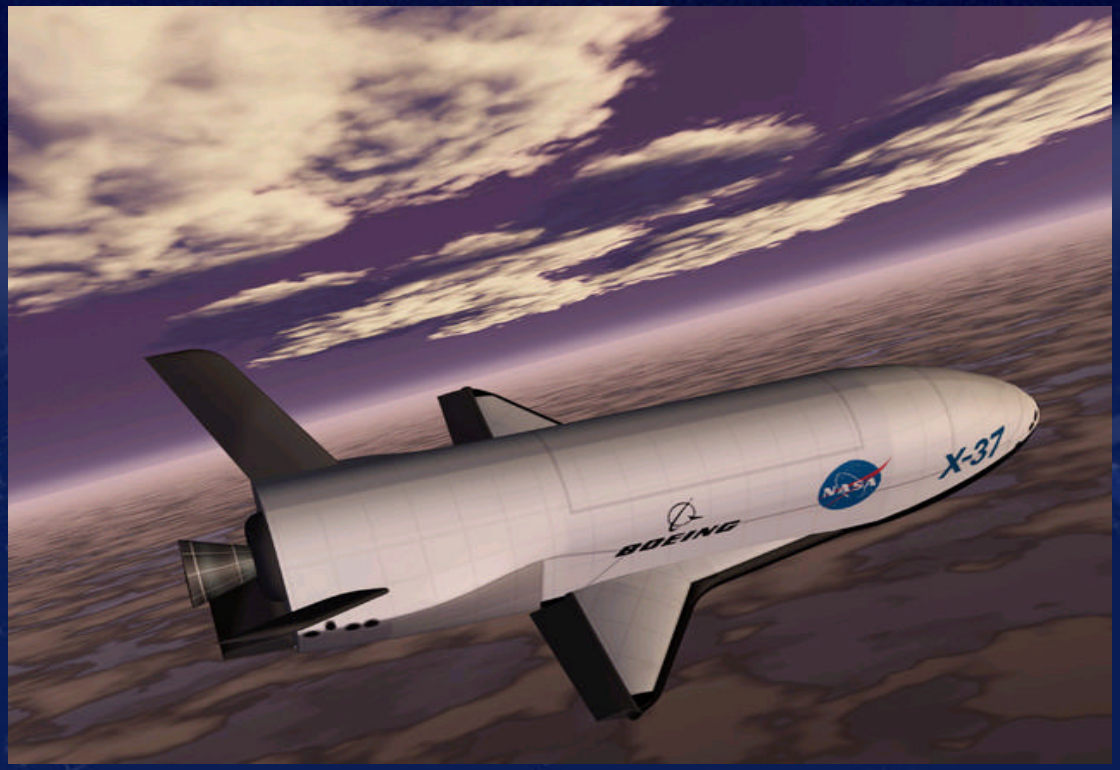
Space Transportation Technology IVHM Session

- **Long-term goal: Reduce cost and increase reliability of space transportation**
- **Demonstrate benefits of in-flight IVHM to the operation of a Reusable Launch Vehicle**
- **Advance this IVHM technology to Technology Readiness Level ~7 within a flight environment**
- **Operate IVHM software on the Vehicle Management Computer**

Technology Goals and Objectives

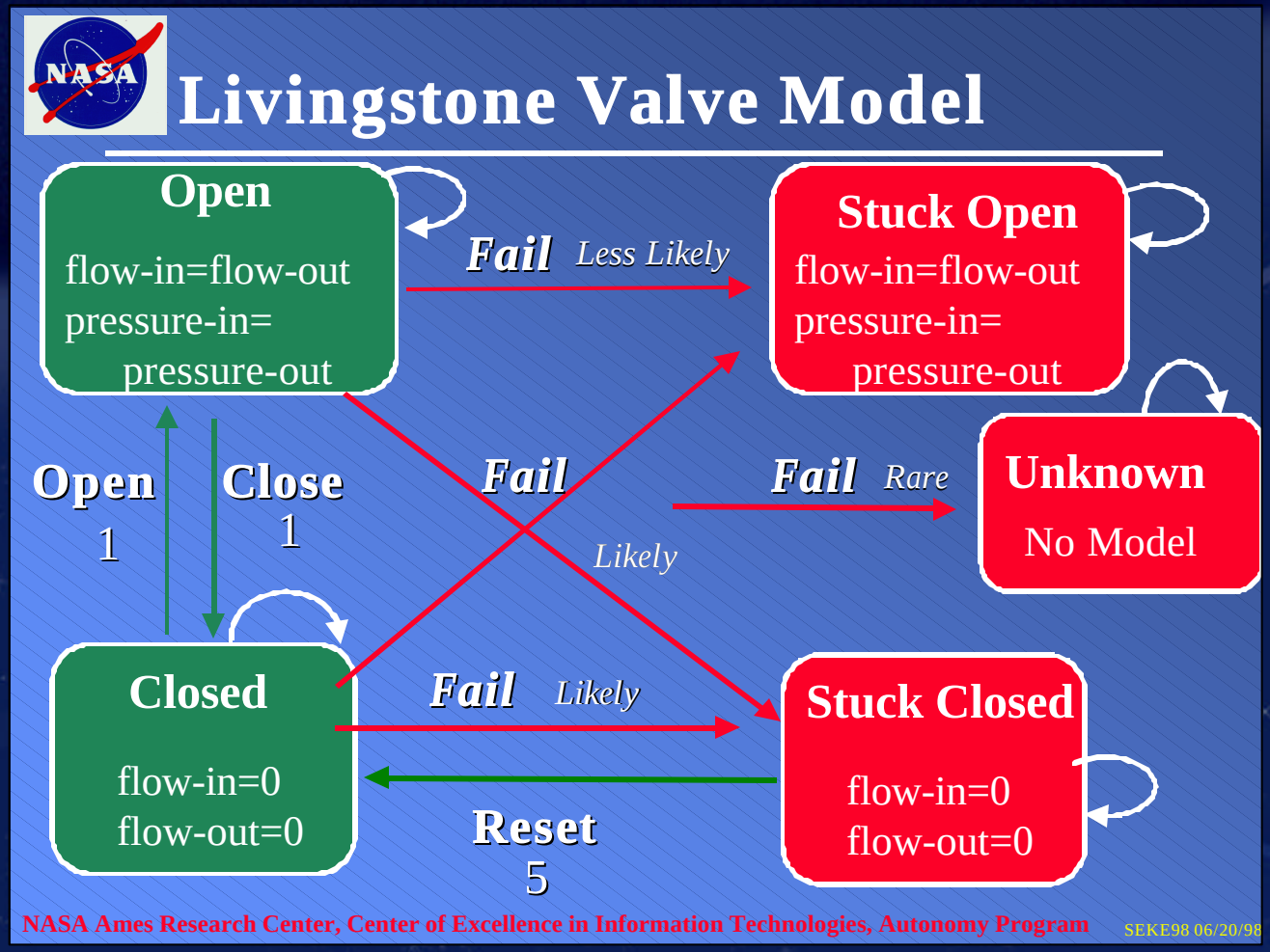


- Unpiloted
- Reusable
- 27.5 feet long
- Mission:
  - launch from Shuttle's cargo bay
  - orbit Earth 21 days
  - De-orbit and land on runway autonomously
- First flight in 2002
- Being built by Boeing for NASA MSFC

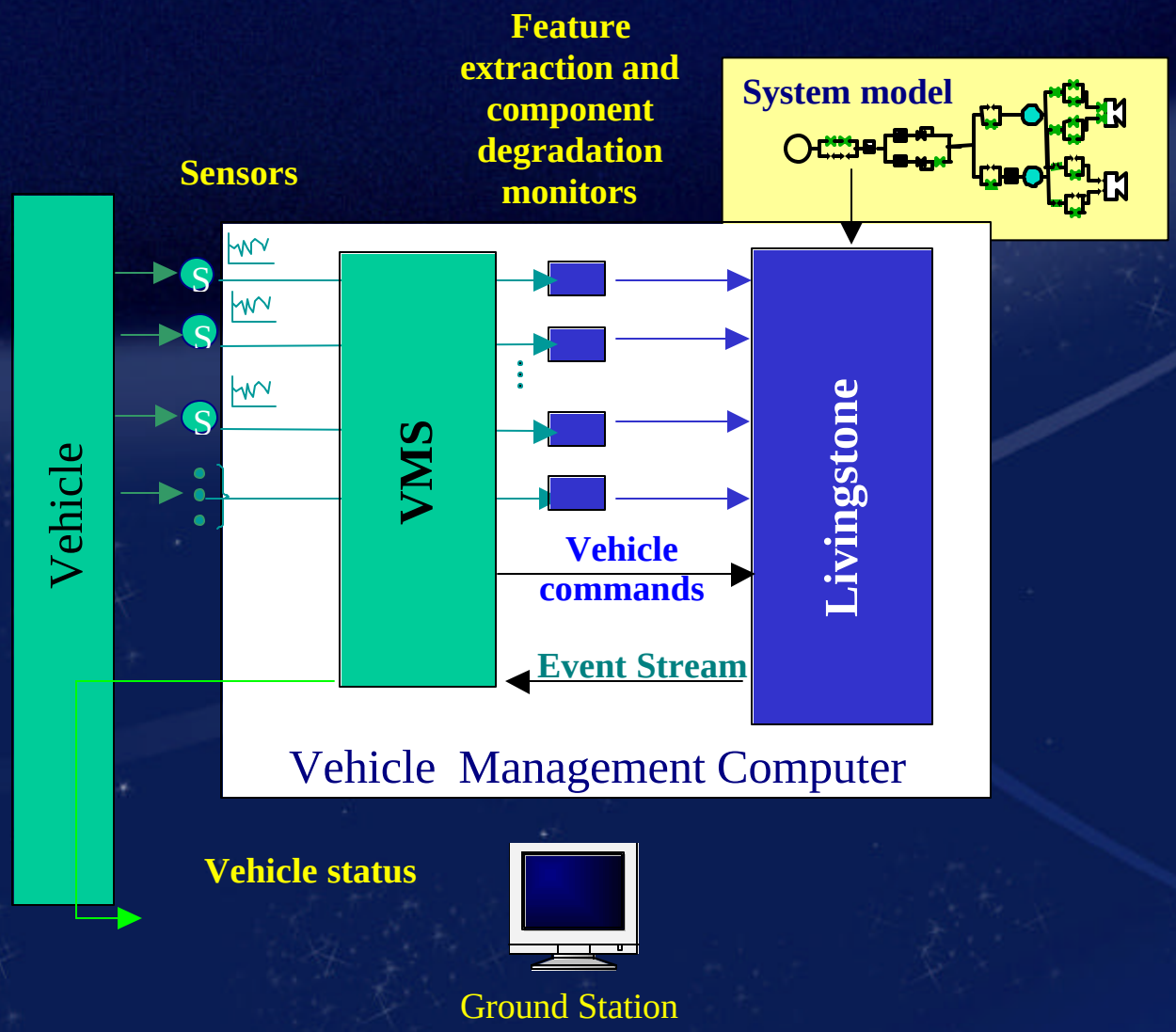
Background: X-37

- Livingstone automates system-level fault diagnosis
- Qualitative, Model-based Reasoning
  - Searches system-wide interactions to detect and isolate failures
  - Eliminates 'hardwiring' pre-defined set of failures
  - Updating and verifying the model is straightforward
  - Streamlines development and maximizes code reusability
- Accomplishment: Successfully flown on Deep Space One
- Also scheduled to fly on X-34

Background: Livingstone



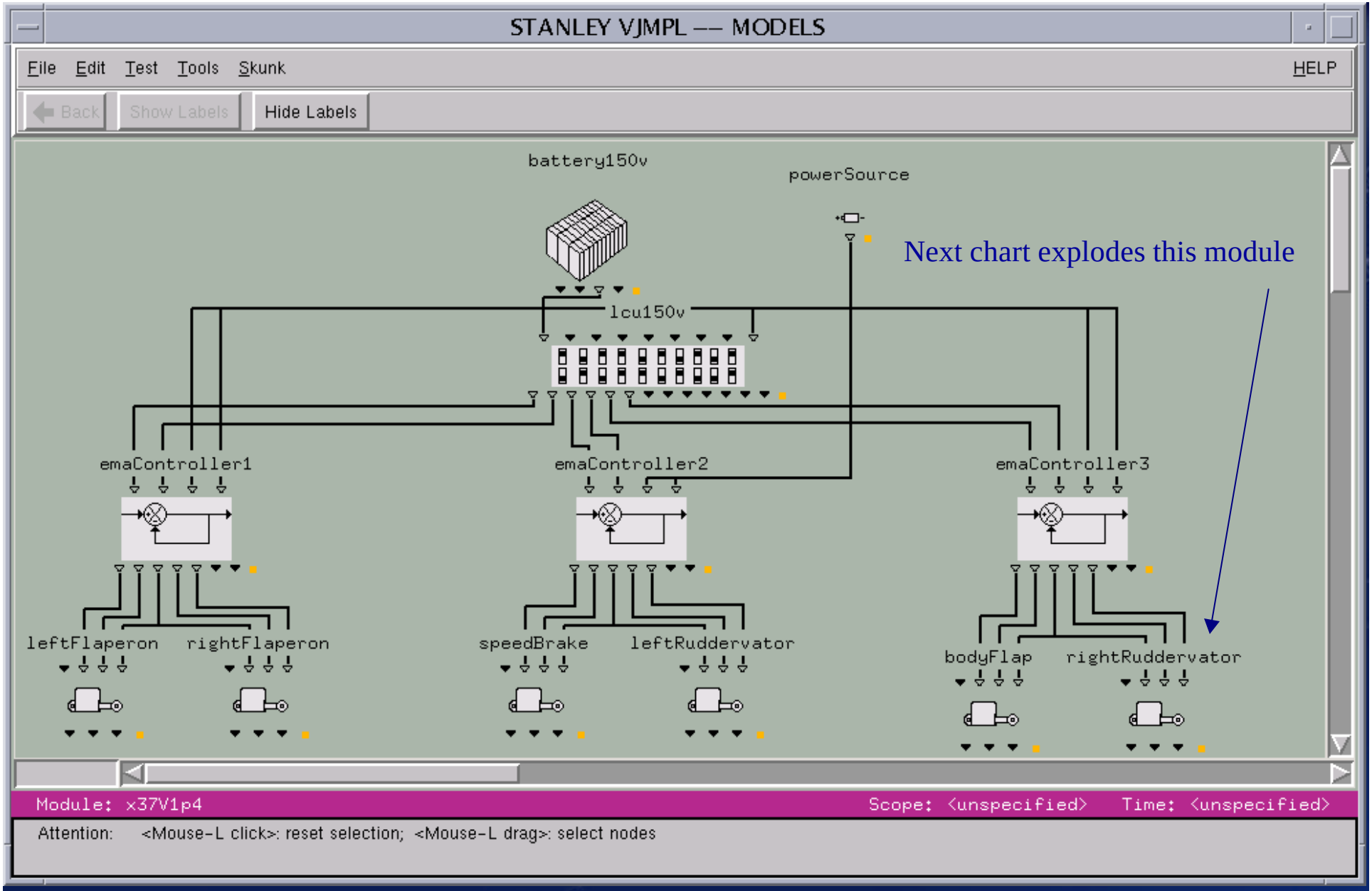
Livingstone Model Example from DS-1



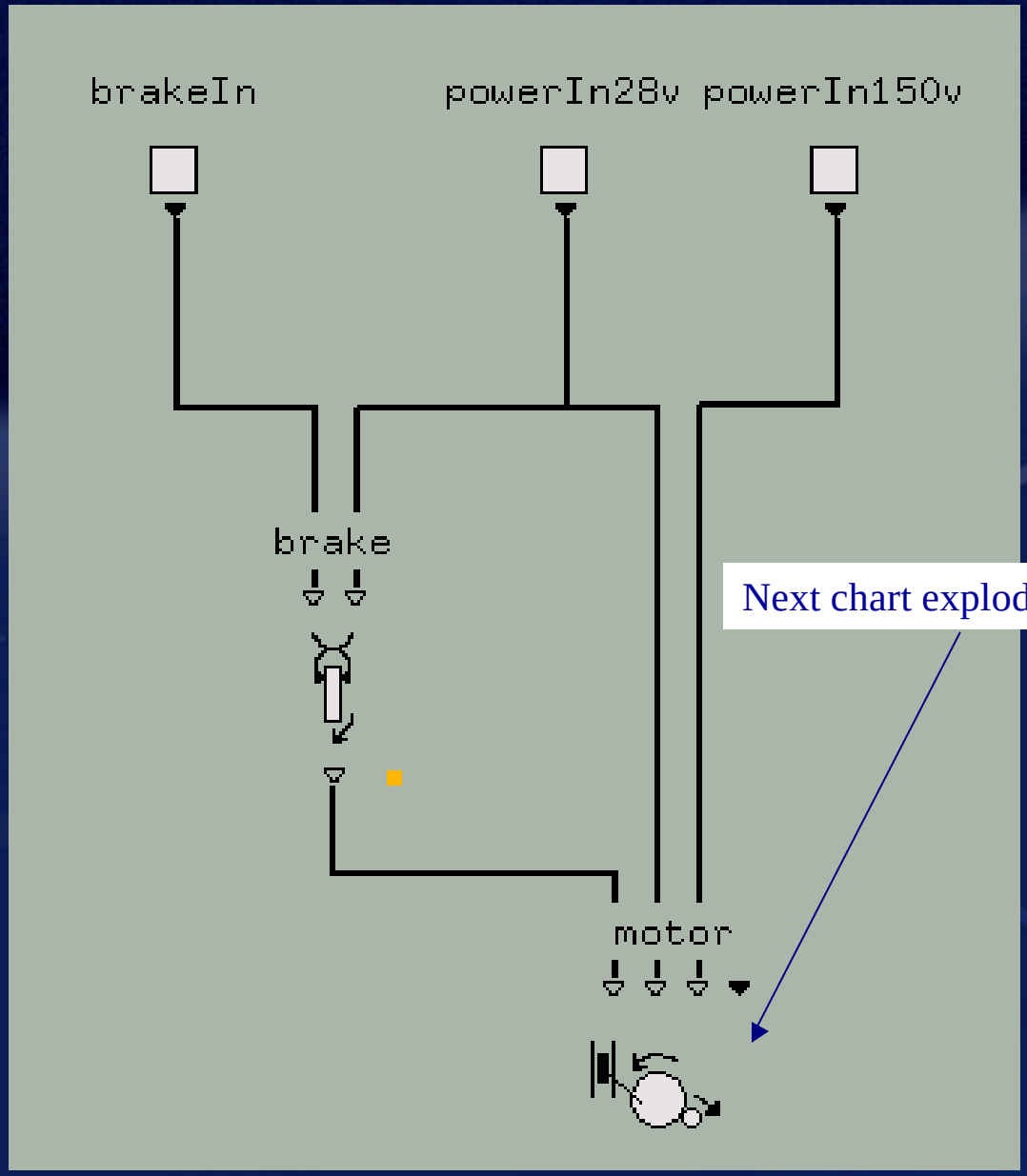
Experiment Overview

- Monitor and diagnose:
  - Electro-Mechanical Actuators (EMA) for control surfaces
  - Associated Electrical Power System components
- Real-time fault detection and isolation
- Diagnosis, not prognosis
- Shadow mode only (no reconfiguration commands)
- Generate advisory recommendations for ground ops

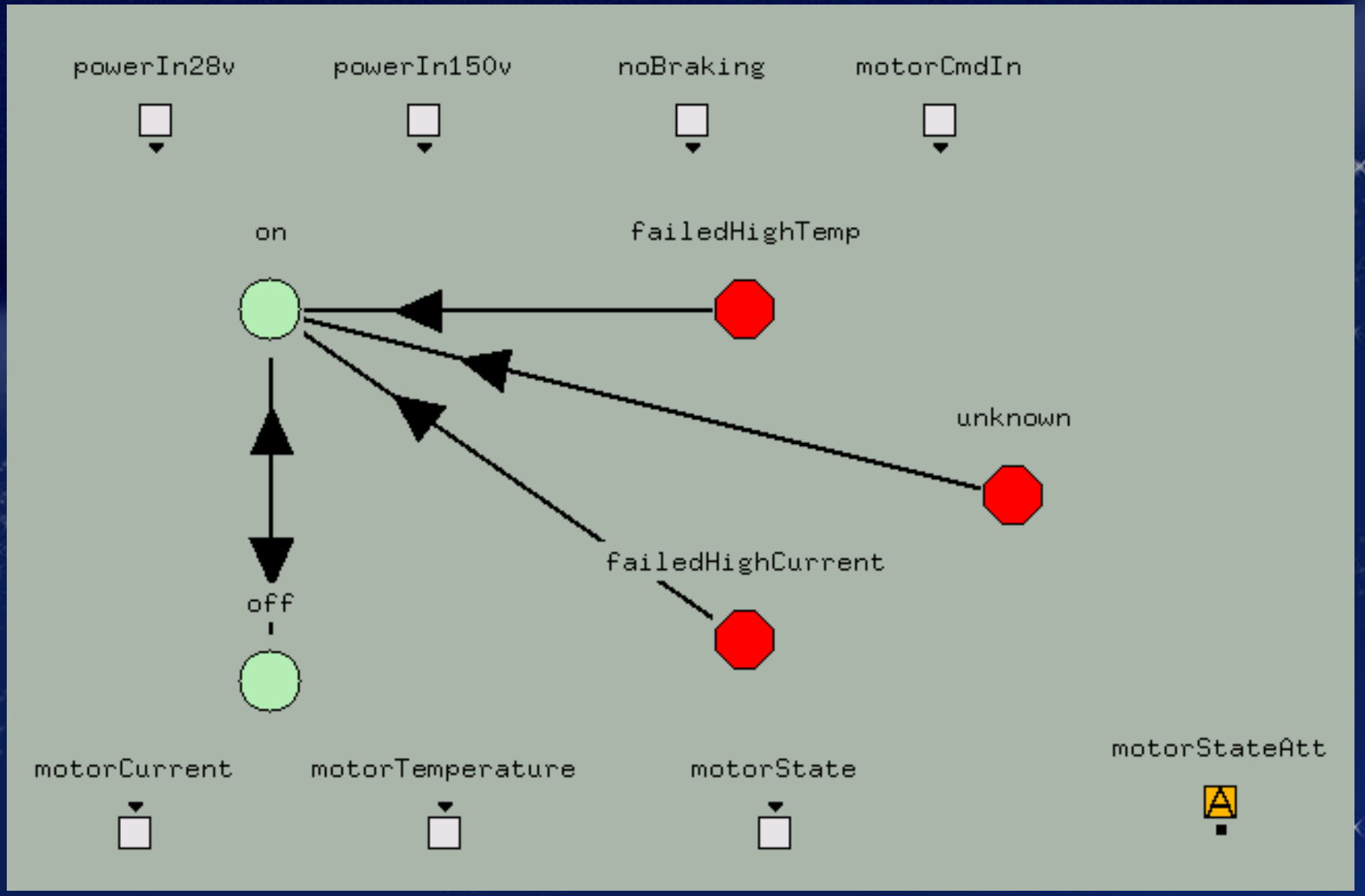
X-37 IVHM Scope



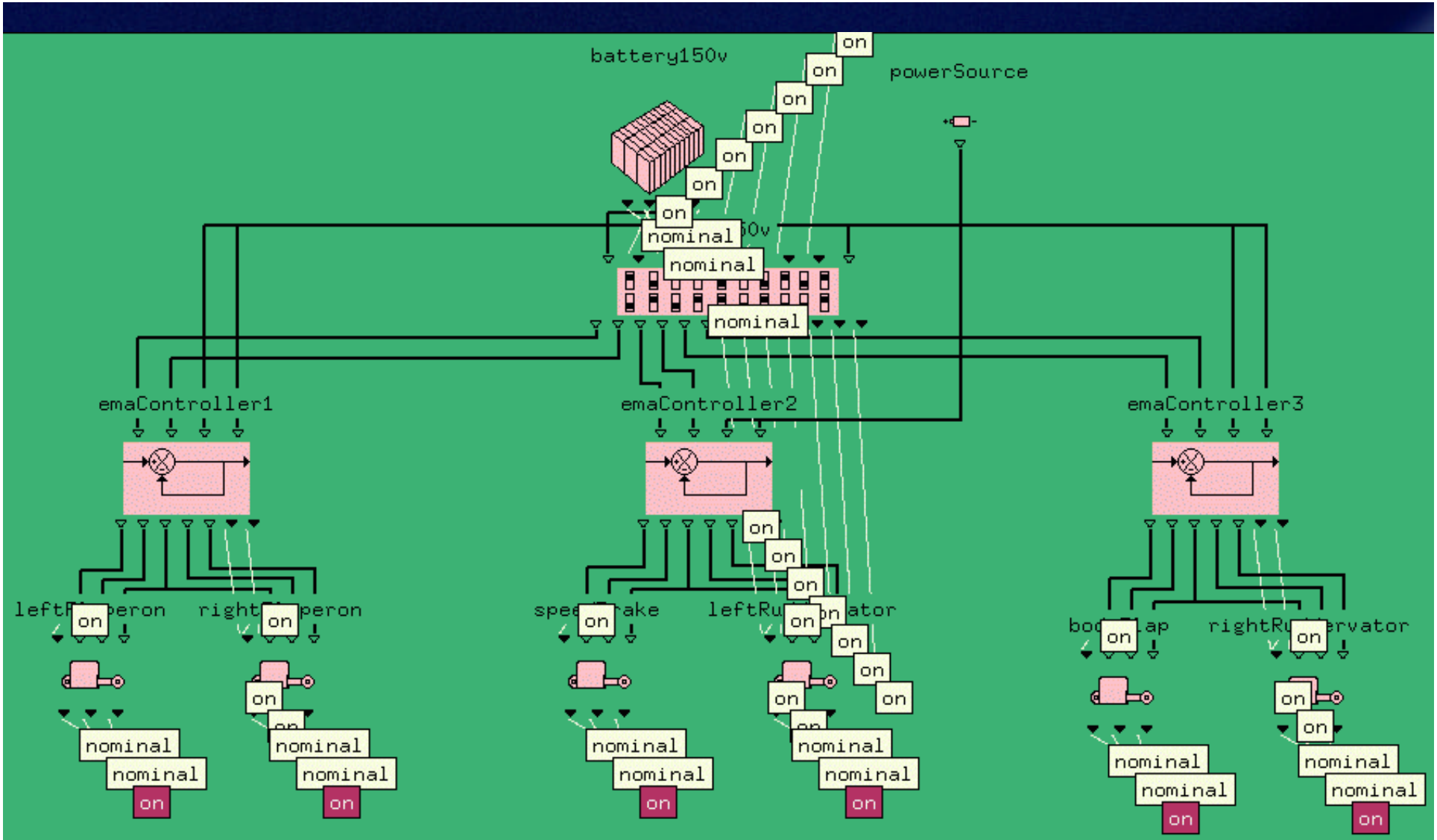
Stanley Interface to Livingstone Model



Right Ruddervator Actuator Detail



Motor state diagram



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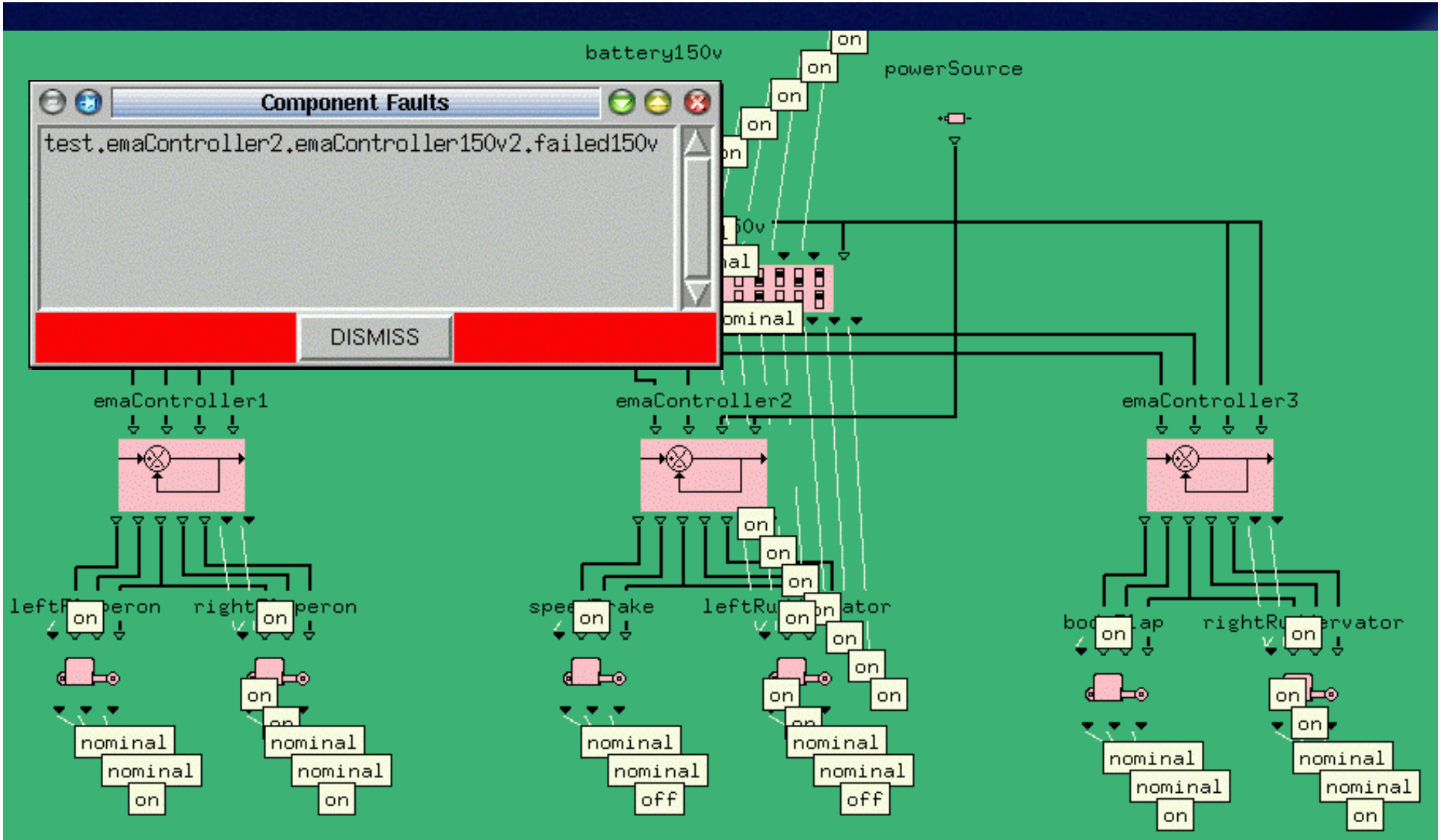
Inferred Nominal State



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Inferred Failure

- The IVHM Experiment's outputs will be provided as inputs to the X-37 Informed Maintenance (IM) Experiment
- The IM software will run in the X-37 ground station, processing IVHM Experiment flight data in real-time
- IM Experiment is being performed by NASA KSC and Boeing
- The IM Experiment's goal is to reduce the cost and time needed to maintain the vehicle

- During the second orbital mission, we will use simulated faults to demonstrate the IVHM software's ability to diagnose them

Simulated Faults

- Livingstone ported from LISP to C++ under VxWorks
- Preliminary design of Interface with Boeing software completed
- Knowledge of X-37 subsystems gained from Boeing experts
- First subset of X-37 model completed

Current Status

- **Limited vehicle resources available to IVHM**
  - **CPU**
  - **Memory**
  - **Telemetry**
  - **May need to descope experiment to fit resource constraints**
- **Rigorous software safety standards**

Challenges

- **03/01/01: Deliver IVHM Ver1 Software to Boeing for B-52-based autonomous approach and landing tests**
- **03/01/02: Deliver IVHM Ver2 Software to Boeing for orbital flights**

Upcoming Milestones

- **Mina Cappuccio**: X-37 L3 PM & Expt Programmatic Lead, mcappuccio@arc.nasa.gov, 650-604-1313
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- **Mark Schwabacher**: Software Lead, mark.schwabacher@arc.nasa.gov, 650-604-4274
- **Scott Poll, Kevin Carbajal**: X-37 Models & Monitors
- **Scott Christa, Benoit Hudson**: Software Integration & Test
- **Dan Clancy, Jim Kurien**: Consulting

People and Contact Information